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INVENTOR(S)					
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TITLE OF THE INVENTION (280 characters max)					
GAIT REHABILITATION METHODS AND APPARATUSES					
Direct all correspondence to: CORRESPONDENCE ADDRESS					
<input type="checkbox"/> Customer Number _____		<div style="border: 1px solid black; padding: 5px; width: fit-content;">Place Customer Number Bar Code Label here</div>			
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<input checked="" type="checkbox"/> Applicant claims small entity status. See 37 CFR 1.27.				FILING FEE AMOUNT (\$)	
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The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government.					
<input checked="" type="checkbox"/> No.					
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Respectfully submitted,

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GAIT REHABILITATION METHODS AND APPARATUSES RELATED APPLICATIONS

5 This application is related to U.S. provisional application serial number 60/542,022, filed February 5, 2004, by inventor Omer Einav et al., U.S. provisional application serial number 60/566,078, filed April 29, 2004, by inventor Omer Einav et al., U.S. provisional application serial number 60/566,079, filed April 29, 2004, by inventor Omer Einav, U.S. provisional application serial number 60/604,615, filed
10 August 25, 2004, by inventor Omer Einav et al., U.S. provisional application filed on even date, entitled "Methods and Apparatus for Rehabilitation and Training", attorney docket number 414/04212, and U.S. provisional application filed on even date, entitled "Rehabilitation with Music", attorney docket number 414/04172, the disclosures of these applications are incorporated herein by reference.

15 FIELD OF THE INVENTION

The present invention relates to methods and apparatuses for rehabilitation.

BACKGROUND OF THE INVENTION

Strokes, accidents and other medical conditions can cause a person to lose the ability to control gait, for example, how to walk or run. During a lengthy rehabilitation
20 process, a patient is taught anew how to control the body parts that contribute to patient gait and locomotion.

One system for providing rehabilitation is described in U.S. Pat. No. 6,666,831 ("the '831 patent"). The '831 patent describes a robotic exoskeleton and a control system for driving the robotic exoskeleton, including a method for making and using the
25 robotic exoskeleton and its control system. The robotic exoskeleton has sensors embedded in it which provide feedback to the control system. Feedback is used from the motion of the legs themselves, as they deviate from a normal gait, to provide corrective pressure and guidance. The position versus time is sensed and compared to a normal gait profile. Various normal profiles are obtained based on studies of the population for age,
30 weight, height and other variables.

Another system for providing rehabilitation is described in U.S. Pat. No. 6,689,075 ("the '075 patent"). The '075 patent describes a support structure which supports powered lifting means for lifting a patient from a wheelchair and moving the

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patient over a powered treadmill where the patient is lowered onto the treadmill. A control panel with a mirror thereon is supported at one end of the support structure, and a touch screen data entry/display device is supported by the panel. Two similar housings are disposed at opposite sides of the treadmill. Each housing pivotally supports a support arm which can swing away from the treadmill to facilitate access to the treadmill. Each support arm pivotally supports a first depending arm, and a second depending arm is pivotally supported therefrom. A pair of servo motors are supported by each support arm and are drivingly connected to the first and second depending arms to independently move the depending arms about the pivot axes thereof. A first attachment cuff is connected to the first depending arm for attachment to a patient's leg just above the knee. A second attachment cuff is connected to the second depending arm for attachment to a patient's ankle. The support arms are vertically adjustable, and the attachment cuffs are horizontally adjustable. The first attachment cuff is vertically adjustable, and the second attachment cuff floats vertically relative to its depending arm. Control means is connected to the drive means for the treadmill and the servo motors which move the depending arms to cause the treadmill and the depending arms to operate in a coordinated manner to cause the legs of the patient to move in a desired gait. Sensor means is also provided for sensing the home position as well as possible over-travel of the knee joint of the device.

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SUMMARY OF THE INVENTION

An aspect of some embodiments of the invention relates to selective and staged rehabilitation of a patient in order to improve the gait of a patient. Various operative components of a patient's gait can be specifically targeted and exercised to achieve patient gait improvement.

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An aspect of some embodiments of the invention relates to providing the ability to receive rehabilitation to a patient while the patient is in a sitting position. The invention optionally includes systems which provide wheelchair access. Alternatively, an active chair is provided which moves up and down, rotates in various directions and optionally includes a separate back support. Also provided are special exercises designed for a patient in a sitting position.

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An aspect of some embodiments of the invention relates to providing rehabilitation therapy that retrains a patient in an extensive range of motion and/or on multiple axes.

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An aspect of some embodiments of the invention relates to rehabilitating patients by using the foot as a primary contact point. Focus on the foot can assist with balance training. In some embodiments, foot focused exercise enables rehabilitation activity to be conducted while in a seated position. Either foot, or both feet, can be optionally
5 utilized as contact points between the patient and the rehabilitation system. In some embodiments of the invention, rotating at least one foot by the ankle in the x, y and z axes is part of the rehabilitation.

An aspect of some embodiments of the invention relates to facilitating patient entry and exit from an array of rehabilitation systems. In some cases, entry and exit can
10 be eased by providing various pieces of a rehabilitation system with the ability to swing open to accept a large sized patient or a wheelchair, for example. In other exemplary embodiments, the chair back spoons the patient, which allows a sliding off and on of the patient with or without the armpit support, and/or pushes the patient forward into a special chair for rehabilitation therapy. In further exemplary embodiments, a belt is used
15 to move the patient into position. Optionally, adjustable bars with armpit supports can lift a patient into rehabilitation position, or alternatively a chair which tips the patient into an exercise position is provided. Optionally, the patient is assisted into a standing position by the rehabilitation system.

An aspect of some embodiments of the invention relates to providing
20 rehabilitation systems which are transportable and/or are small in size for use in locations including small clinics, nursing homes, residential homes or places of work. In an exemplary embodiment of the invention, a rehabilitation system is provided which is transportable by suitcase. Optionally, a rehabilitation system is provided which is usable from either side.

25 An aspect of some embodiments of the invention relates to being able to rehabilitate a selected side of the patient.

An aspect of some embodiments of the invention relates to providing a harness for controllable weight support and additionally for hip rehabilitation. Optionally, the harness is used in combination with at least a seat. Optionally, the harness is used in
30 combination with at least an armpit support.

An aspect of some embodiments of the invention relates to providing rehabilitation systems which are used in combination with a wheelchair, crutches, cane or walker in order to rehabilitate gait.

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An aspect of some embodiments of the invention relates to providing a method for gait rehabilitation, comprising:

identifying deficient gait elements;

5 exercising said deficient gait elements individually using a rehabilitation apparatus; and

exercising said deficient gait elements in concert using said rehabilitation apparatus.

An aspect of some embodiments of the invention relates to providing a method for gait rehabilitation further comprising exercising a complex gait element.

10 An aspect of some embodiments of the invention relates to providing a method for gait rehabilitation wherein a complex gait element is chosen from the group consisting of balance, overcoming obstacles, climbing steps, movement up slopes and varying speed.

BRIEF DESCRIPTION OF THE FIGURES

15 Non-limiting embodiments of the invention will be described with reference to the following description of exemplary embodiments, in conjunction with the figures. The figures are generally not shown to scale and any measurements are only meant to be exemplary and not necessarily limiting. In the figures, identical structures, elements or parts which appear in more than one figure are preferably labeled with a same or similar
20 number in all the figures in which they appear, in which:

FIG. 1 is a flowchart depicting a method of gait rehabilitation of a patient in accordance with an exemplary embodiment of the invention;

FIG. 2 is a flowchart depicting a progression of rehabilitative steps in accordance with an exemplary embodiment of the invention;

25 FIG. 3 is an illustration of a portable side rehabilitation apparatus in accordance with an exemplary embodiment of the invention;

FIG. 4 is an illustration of a two-sided rehabilitation apparatus in accordance with an exemplary embodiment of the invention;

30 FIG. 5 is an illustration of a two-sided rehabilitation apparatus using adjustable handling bars in accordance with an exemplary embodiment of the invention;

FIG. 6 is a view of a rehabilitation apparatus being used in conjunction with a support harness in an exemplary embodiment of the invention;

FIG. 7 is a view of a rehabilitation apparatus being used in conjunction with a support chair in an exemplary embodiment of the invention; and

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FIGS. 8A-C are views of various modes of operation of a support chair in an exemplary embodiment of the invention.

DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENTS

Referring now to FIG. 1, a flowchart 100 is presented which sets forth a method of gait rehabilitation in an exemplary embodiment of the invention. At action 102, gait rehabilitation commences with the identification of deficient elements in a particular patient's gait. Optionally, the patient is exposed to various optional tests and/or exercises which help a rehabilitation assistant evaluate the extent of rehabilitation necessary to restore the patient's gait. Tests are optionally conducted in conjunction with the methods and apparatuses described herein and/or with methods and apparatuses known to those skilled in the art. In some exemplary embodiments of the invention, elements of a gait include foot and ankle movement, leg movement, hip movement, shoulder movement, arm movement, and more advanced elements such as balance, overcoming obstacles and varying speeds. Optionally, one or more of these elements are rehabilitated using the methods and apparatuses described herein. After the patient's baseline gait has been evaluated, therapy goals are set at action 103. It should be noted that goals can be set either before or after the initial evaluation at action 102. In addition, therapy goals can be changed throughout the therapy process as the patient rehabilitates depending on, for example, one or more of the patient's progress, options for rehabilitation and/or advances in rehabilitation medicine. Once deficient elements have been identified, at action 104 these deficient elements are optionally exercised individually possibly with the objective of increased control and/or strength. Optionally, the elements are trained in series. That is, each element is trained one after another. Optionally, some or all of the elements are trained in parallel. To wit, a plurality of elements are trained at the same time. At action 105, the patient's progress in rehabilitation is reevaluated allowing for adjustments to be made in the rehabilitation process. As the patient begins to master individual elements of a gait, some or all of these elements are optionally exercised together at action 106. In other words, the patient's abilities are optionally built up using individual elements at first, then adding elements in combination. The patient's progress in rehabilitation is optionally reevaluated allowing for adjustments to be made in the rehabilitation process at action 107. Complex gait attributes, such as overcoming obstacles and varying speeds, are optionally exercised at action 108. At action 110, the patient's progress in rehabilitation is reevaluated allowing for adjustments to be made in the rehabilitation therapy process.

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Balance, as an element of gait, is optionally exercised at any or all of the actions 104-108. Optionally, any or all of the actions 104-108 are performed with a weight relieving apparatus or in water. Optionally, actions 105, 107 and 110 can be performed at any time during the rehabilitation process and can be combined or expanded to include more or less than three reevaluations. Optionally, exercise can be paused and resumed for any reason, including to allow the patient time to rest. The patient and/or a supervising health care professional can be provided with a switch which puts an apparatus into an operational/non-operational status. Optionally, a rehabilitation apparatus can be stopped at any time using a switch like a "dead-man switch".

FIG. 2 depicts a flowchart 200 which illustrates a method of gait rehabilitation in an exemplary embodiment of the invention. For the purposes of this embodiment, a determination at action 102 has identified multiple deficiencies (e.g. foot/ankle, legs, hips, shoulders, arms, balance) in a particular patient's gait. A program of gait rehabilitation in this exemplary embodiment focuses on the gradual development of a patient's abilities. Therefore, the method commences at action 202 with foot and ankle exercises. In an exemplary embodiment of the invention, these foot and ankle exercises represent a basic building block in a patient's gait rehabilitation. Logically, the feet and ankles first need to be trained in order to allow the patient to stand up and bear weight on them. Optionally, foot and ankle exercises can be performed from the seated position, for example from a wheelchair. In some embodiments of the invention, exercises include moving the foot to pre-selected angles and rotations which help the patient achieve a particular gait (e.g. walking, climbing stairs, walking up a slope), exercises can also include asking the patient to exert a specific force on the foot pedal and/or asking the patient to shift weight from toe to ankle or from side to side, for example.

In an exemplary embodiment of the invention, an apparatus is provided that can accomplish at least these exercises. Optionally, these exercises are performed on a plurality of apparatuses. In an exemplary embodiment of the invention, an apparatus comprises robotic moving parts (e.g. robotic arms). Optionally, an exercise apparatus is provided with a controller. Optionally or additionally, the controller is a personal computer or a dedicated embedded computer. In an exemplary embodiment of the invention, the apparatus is provided with sensors which monitor at least the status of the patient and the apparatus.

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As foot control and strength develop, gait rehabilitation progresses with leg exercises at action 204. In an exemplary embodiment of the invention, the patient progresses from foot and ankle exercises to leg exercises in order to stand up. Leg exercises are optionally commenced from a sitting position and graduate to a standing position. Alternatively, leg exercises occur from a standing position. In other embodiments of the invention, leg exercises are performed while the patient is in a weight relieving apparatus, such as a harness. Depending on the patient's needs or the equipment available for rehabilitation, leg exercises can be performed on either leg, both legs simultaneously, only on one leg, or on only one leg at a time. In some exemplary embodiments of the invention, sensors are located on a rehabilitation apparatus which detect leg movement and analyze the leg movement achieved during exercise relative to recommended leg positions, or movement points. Optionally, a patient's leg is attached to a rehabilitational apparatus at the foot, instead of a location on the leg, in order to practice leg exercises. Such an attachment can potentially provide a number of advantages, including assisting with balance training. For example, being attached for support at the leg provides the patient with unnatural and possibly rehabilitation hampering support. However, support from the foot is natural and usual as this support is usually derived from the floor on which the patient is standing.

In an exemplary embodiment of the invention, leg exercises can be performed in three basic modes of operation. The first mode is where motive force during rehabilitation is derived from the patient. This mode is likely used when the patient is nearing the end of rehabilitation or in the case where a healthy side or element is being observed in order to determine the rehabilitation goal for an unhealthy part of the patient. The second optional mode of operation is passive. That is, where the rehabilitation apparatus provides the motive force to the patient. This mode is likely used when the patient is at the beginning of rehabilitation and is still too weak, uncoordinated or the like to move the rehabilitation apparatus and/or the paretic body parts. In an exemplary embodiment, exercise is performed in this mode while the patient is in a harness. Exercise in this fashion enables a reduction in the amount of weight borne by the patient. There are also safety advantages (e.g. the patient cannot fall down while being held up by the harness). In an embodiment where the harness bears the entire weight of the patient, the exercise apparatus can provide resistance to facilitate training. Optionally, the apparatus provides resistance in the absence of the harness or if the weight is only partially borne by the harness. Resistance can also be added to the

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exercise routine by affixing weights to the patient. The third optional mode is a combination of the two, whereby the patient is supplying motive force while being assisted by the rehabilitation apparatus. In the third optional mode, the rehabilitation apparatus optionally supplies additional force to a patient's actions on various apparatus components, such as a foot pedal. Optionally, the apparatus nudges the patient, as in the case of the support chair 702 when assisting the patient with standing up.

Optionally, the patient may be supported or partially supported while in any of the three modes. Also, it should be noted that these three modes of operation can be applied to any of the actions 202-212 of the rehabilitative process and while they are characterized as likely at the beginning and likely towards the end of rehabilitation, the modes can be used at anytime as is desired and/or necessary for rehabilitating the patient.

In an exemplary embodiment of the invention, hip and torso movement relative to leg motion is measured in order to gauge the patient's needs for rehabilitation using them in combination, to rehabilitate the patient's use of all three together and in order to ascertain the patient's progress in using them in concert.

At action 206, hip motion exercises and analysis are included in gait rehabilitation in an exemplary embodiment of the invention. As a patient progresses from sitting to standing to walking, proper hip movement becomes important. One way to rehabilitate hip movement is to use sensors to monitor the hips as the patient performs rehabilitation exercises. Optionally, the sensors are attached to a rehabilitation apparatus like a harness in which the patient is strapped. As the patient proceeds to take steps the harness sensors detect swing motion of the patient where the motion of the patient may be unbalanced or insufficiently supported by the patient's body parts. Analysis of the swing data can provide the patient with instructive information on improving hip angle and positioning. In some exemplary embodiments, a specially adapted chair is used to support and measure hip motion during rehabilitation. Optionally, exercises are provided in which the patient moves the hip in order to assist the passive motion of a paretic leg.

Shoulder motion is rehabilitated and optionally analyzed at action 208. A camera or sensors can be used to detect and record shoulder movement of the patient in order to provide a baseline of performance and to monitor the progress of the rehabilitation of this element. In an exemplary embodiment of the invention, position sensors are attached to the patient's body which signal movement of the patient to a controller. The

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sensors are optionally wireless. In some exemplary embodiments of the invention, the cameras are used to image detect the limbs of the patient and/or patches affixed to the patient which move when the patient is in motion. Recorded shoulder movement can be compared to a goal movement profile or previous recordings of the patient's movement for analysis. Optionally, this record and playback or comparison technique can be used for any step of rehabilitation. Optionally, the patient imitates a previously recorded movement profile which is presented to the patient during rehabilitation and which functions as the goal movement profile. The previously recorded movement profile can be from the patient's movement or that of another. Optionally, the movement profile is generated by the controller. The shoulders play an important role in a patient's gait, for example with regards to arm movement. In an exemplary embodiment of the invention, articulated robotic arms are affixed to the patient which assist the movement of the arms and shoulders in combination. Optionally, the patient is attached to the robotic arms through the use of restraints. The patient can be attached to the robotic assistance at any part of the body that will provide suitable rehabilitation exercise to the patient. In some exemplary embodiments of the invention, the patient is not affixed to the robotic assistance, but rather, holds on to the robotic apparatuses for movement guidance. The movement trains the arms and shoulders to move under various conditions like walking, stair climbing, etc. Optionally, the exercises provided to the patient are varied depending on the patient's need for rehabilitation. An example of an exercise for rehabilitating shoulders is moving the patient's arms and shoulders in a skiing motion. Robotic assistance can be optionally provided on either or both sides of the patient, above and/or below the patient or in front of and/or behind the patient. Optionally, robotic assistance is provided utilizing a combination of these locations. For example, a robotic arm is located on each side of the patient and is either affixed to or is grasped by the exercising patient. As the patient exercises, the robotic arms can guide the patient in moving his/her arms appropriately (e.g. while walking).

Arm movement is rehabilitated at action 210 in an exemplary embodiment of the invention. As in the previous rehabilitation steps, cameras, sensors, or even a robotic arm, can detect and/or record arm motion. In the passive mode, the arm(s) needing rehabilitation are moved by the rehabilitation apparatus along a recommended path of motion. In assisted mode, the patient supplies some modicum of arm movement with input from the rehabilitation apparatus as needed.

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In an exemplary embodiment of the invention, action 212 reinforces individual gait element improvement within the context of some or all of the elements cooperating with each other. For example, it is desirable to train coordinated leg and arm movement in some embodiments of the invention (*i.e.* left leg forward means right arm forward).

5 As described above, coordinated movements such as walking and simulated skiing, for example, can be exercised by the patient in order to rehabilitate combination movements of the various body elements. Another combination movement that is exercised in an exemplary embodiment of the invention is turning. Optionally, coordinated movements and/or gait can be assisted by playing rhythmic music to the patient during exercise.

10 In an exemplary embodiment of the invention, the patient moves a healthy body part on one side, which is recorded (and possibly filtered and/or modified depending on the rehabilitation needs of the patient) and then the healthy movement is "played" to the paretic side by the rehabilitation apparatus, thereby imparting the patient's natural gait to the body part being rehabilitated through kinesthetic feedback. Optionally, the
15 apparatus "plays" the nominal gait to the paretic body part, so the patient gets the feel of the nominal movement, then the patient repeats the movement using the paretic body part, either with assistance or without assistance from the apparatus.

In exemplary embodiments of the invention, these exercises can be performed either sitting or standing, or while suspended from a weight relieving apparatus such as
20 a harness. It should also be noted that patients will present themselves requiring varied degrees of gait rehabilitation and therefore some exercises are not required or desirable. For example, some patients will present themselves not being confined to a wheelchair or a sitting position, or need only rehabilitation on one side. Optionally, a patient who is missing at least one limb has their gait rehabilitated utilizing at least one prosthetic limb.

25 Optionally, a patient can perform these exercises with an object designed to assist with movement (*e.g.* a wheelchair, a walker, crutches or a cane). In an exemplary embodiment of the invention, when a patient is using wheelchair, a support chair, such as the type depicted in FIGS. 7 and 8, is not required. The wheelchair is moved into position on an apparatus and exercise can be performed from the seated position in the
30 wheelchair, or the patient can be assisted to a non-seated exercise position as described herein. In some exemplary embodiments, the frame of an apparatus swings open to allow entry of a wheelchair or walker. Patients requiring the assistance of crutches or a cane can exercise in an apparatus which is adapted to be wide enough to provide side room for the walking appliances. It should be noted that in some exemplary

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embodiments of the invention, walking appliances used in conjunction with the apparatus may be slightly longer than would normally be used to account for the foot pedals being slightly off the floor.

Referring now to FIG. 3, an illustration of a portable side rehabilitation apparatus 300 in accordance with an exemplary embodiment of the invention is provided. The apparatus 300 is optionally utilized to rehabilitate the gait of a patient in conjunction with the methods described in FIGS. 1 and 2. In an exemplary embodiment of the invention, the portable side rehabilitation apparatus 300 operates in the x and z axes. In this embodiment, x-axis means that from the patient's point of view, the positive x-axis extends in a straight forward direction of travel for the patient. The z-axis in this embodiment means that from the patient's point of view, movement is up in the positive z-axis and down is in the negative z-axis. Located on the apparatus 300 are motors 302 and 304 for providing movement to components of the apparatus 300 along these axes. A patient being rehabilitated straps a foot into a foot pedal 306 which is provided to move in both the x and z axes. In addition to x and z axial movement, in an exemplary embodiment of the invention, the foot pedal 306 rotates in multiple directions as depicted by arrows 308 and 310 in FIG. 3. Optionally, the foot pedal 306 can be equipped with pressure sensors in order to gauge and analyze the patient's strength in that foot.

In an exemplary embodiment of the invention, the foot pedal 306 has the capability to extend and retract along the y-axis of FIG. 3. Patient turning can be exercised by utilizing at least the rotational and extension capabilities of the foot pedal 306 while the patient follows a hypothetical curved path. Optionally, turning is exercised by widening the stance of the patient during exercise.

While one of the patient's feet is strapped into the foot pedal 306, the other foot can be at rest, on a treadmill-like track 312 or even on a second foot pedal, similar to foot pedal 306. Therefore, in some exemplary embodiments of the invention, only one side of the patient is exercised. The patient may be optionally standing or sitting while using the apparatus 300. For example, a patient sitting down can use the rotational ability of the foot pedal 306 to build strength and control in the foot and lower leg. In some exemplary embodiments of the invention, the apparatus 300 is provided with anti-tip extending legs, which provide stability to the patient strapped into the apparatus as well as the apparatus. Optionally, the foot pedal 306 can be inserted from either side of the apparatus 300. In an exemplary embodiment of the invention, switching the side

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from which the foot pedal is inserted can provide exercise movement for both sides of the patient without having to substantially move the apparatus. In some exemplary embodiments, the apparatus 300 is adapted to be used in the water. Use in the water is accomplished by waterproofing components of the apparatus which are sensitive to water. This may include encapsulating any sensors being used and/or using waterproof sensors. Optionally, the apparatus can be hydraulically operated to take advantage of the ample water supply. In exemplary embodiments of the invention, the travel in the z axis is only a few centimeters and the travel (*i.e.* step) in the x-axis is only approximately 20-50 centimeters, therefore the apparatus can be low to the ground and relatively short in length. In an exemplary embodiment of the invention, the low profile of the apparatus allows it to be used with a chair. As a result, an additional optional feature of the apparatus 300 is that it is portable. In some exemplary embodiments of the invention, the track 312 is at a level so that the patient's body weight is on the foot on the track. Optionally, the foot pedal 306 is provided with quick release bindings, like ski bindings, to avoid unwanted motion being imparted to the patient. Thus, in some embodiments of the invention a lower power motor is used for moving the patient's leg that is being rehabilitated, since the patient's body weight is not being supported on it. Use of a lower powered motor, and hence smaller/lighter motor, also enhances the portability of the apparatus 300. Various power sources can be used including, but not limited to, battery and/or AC or DC current.

In an exemplary embodiment of the invention, the foot pedal 306 is attached to the apparatus 300 not from the side, as depicted in FIG. 3, but from the bottom of the foot pedal, maintaining the previous functionality of the apparatus 300.

Optionally, the apparatus 300 is used in concert with prosthetic limbs, for example a prosthetic foot or leg. The prosthetic devices are either secured to the apparatus before the patient mounts the apparatus 300 or, in the alternative, the devices are attached to the patient before the patient gets on the apparatus. Optionally, rehabilitation exercises are modified to account for the use of prosthetics. In an exemplary embodiment of the invention, the patient exercises both the natural leg and the prosthetic leg together. In an exemplary embodiment of the invention, the patient exercises a prosthetic limb in coordination with other body parts. In an exemplary embodiment of the invention, exercise is performed with the assistance of a walking aid such as a cane, crutches or a walker.

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An illustration of a two-sided rehabilitation apparatus in accordance with an exemplary embodiment of the invention is depicted in FIG. 4. The apparatus 400 can be used with the methods for gait rehabilitation described in FIGS. 1 and 2. In this embodiment, an apparatus 400 is provided with a left foot pedal 402 and a right foot pedal 404. Optionally, this apparatus 400 allows movement of the foot pedals 402 and 404 in the x and z axes. The apparatus 400 also includes a frame 406 in some exemplary embodiments. Sensors are optionally attached to the frame 406 in order to measure the motion of legs, hips, shoulders, and/or arms relative to walking points. These sensors are optionally operatively connected to a data processing device for analysis of the motion recorded and for planning rehabilitation. In certain exemplary embodiments, a camera is used to track the patient's movement.

The frame 406 is modified in some embodiments to include an upper structure 408 which can include a vertical adjustment system 410, for taller or shorter than average patients (e.g. children), or body weight support apparatuses such as a harness 602 (depicted in FIG. 6), hangers, or bars 500 (depicted in FIG. 5). In some exemplary embodiments, the frame 406 is also provided with a display unit 414. The display unit 414 can function as a television, or it can contribute to the rehabilitation of the patient by incorporating games which stimulate particular exercises, display exercise related data, provide virtual reality experiences (e.g. kicking a ball, climbing steps, avoiding obstacles) or even just projecting scenery (e.g. walking in the park) into the routine. Optionally, the apparatus 400 provides a support chair 702 (depicted in FIGS. 7 and 8). In some exemplary embodiments, the apparatus 400 can be used in water. Optionally, real objects are used in conjunction with the rehabilitation of the patient (e.g. a real ball is kicked by the patient, a step is placed on the apparatus which the patient must overcome).

In an exemplary embodiment of the invention, patients' rehabilitation is assisted by feedback based on a target movement profile in view of their current movements. Feedback can be in the form of beeps and/or visual cues and other similar video and audio prompts. This is particularly useful for patients with Parkinson's who have a gait problem because they cannot properly gauge step size. Through feedback, the proper step size can be relearned. Feedback is optionally implemented with any of the methods and/or apparatuses described herein. For example, in an exercise where the patient imitates a movement seen on the display, or imitates a previously recorded movement profile, the patient can be guided through exercise via kinesthetic feedback as the

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controller senses patient movement, calculates deviation from the goal movement profile, and prompts the patient to move according to the goal profile. Optionally prompting is achieved through vibration. Optionally, prompting is performed by the apparatus actually moving or nudging the patient in the appropriate direction.

- 5 In order to accommodate patients who would have trouble mounting a rehabilitation apparatus 400, the apparatus 400 optionally incorporates features to make entry and exit more feasible, and reduce need for human help. In some embodiments of the invention, the two sides of the frame 406 can swing open in order to allow entry and exit of a patient (particularly in the case where a patient is wheelchair bound).
- 10 Optionally, the sides of the frame 406 swing open during exercise to allow the patient to "bail out" of the apparatus. Optionally, a belt can be used to pull the patient into an exercise position in the apparatus 400. FIG. 5 depicts how a patient can be raised into exercise position by using bars 500 with armpit supports 502 and at least one piston 504 to raise and lower the bars 500. Initially, a patient is seated on chair 506. While the
- 15 patient is seated, the patient's arms are placed over the armpit supports 502. The patient is then lifted from a seated position by using at least one piston 504 to raise up the bars 500. The patient hanging from the armpit supports 502, is thusly lifted from the seated position. In some exemplary embodiments, the invention utilizes a chair 506 which tips and/or raises the patient into exercise position. Optionally, piston 508 is used to raise
- 20 and lower the chair. Optionally, the chair's rear moves up in relation to the chair's front, thereby "tipping" the patient into exercise position.

- FIG. 6 depicts a rehabilitation apparatus 600 which can be used in the methods described in FIGS. 1 and 2 in order to rehabilitate the gait of a patient. In some exemplary embodiments of the invention, the apparatus 600 is provided with a harness
- 25 602 which supports some or all of the weight of the patient being rehabilitated. One use of the harness 602 is to measure and analyze a patient's gait while the patient is attached to the harness. In an exemplary embodiment of the invention, a patient is partially suspended from the harness 602 and commences forward walking motion. Partial suspension is achieved by first identifying a target weight at which the patient is to
- 30 exercise. Second, a pressure sensor measuring the patient's exerted pressure on the apparatus and/or a weight sensor on the harness is indexed while the harness with the patient inside is moved away from the apparatus until the goal weight is achieved. In an exemplary embodiment of the invention, movement of the harness away from the apparatus is conducted slowly and with a delayed response to prevent unwanted patient

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movement during exercise. While the patient is moving, the harness 602, which is operationally connected to sensors, monitors the patient's gait. The sensors may optionally monitor the patient's position, acceleration, force, and/or velocity. The data output by the sensors is analyzed and thus, anomalies in the gait are detected, either by the controller or by a healthcare professional. From this data analysis of the gait, it can be determined where improvements need to be made. Optionally, the controller gives advisory instructions on how to improve the patient's gait. Optionally, the patient's gait is played back in slow motion for detailed review. Optionally, gait analysis includes comparison of movement to measurements conducted by a neural network. In some exemplary embodiments, a patient strapped into a harness 602 is lifted into exercise position by using at least one piston 504. Another use of the harness 602 is to allow the patient to exercise without bearing the patient's full weight on the rehabilitating limbs. As strength and control return to the patient, weight can be gradually added until the patient is bearing full weight. In an exemplary embodiment of the invention, weights are added to the exercise routine to increase resistance to movement.

Turning now to FIG. 7, a rehabilitation apparatus 700 can be seen being used in conjunction with a support chair 702. In alternate embodiments of the invention, the chair 702 is provided with the ability to move up and down, rotate in various directions and is provided with a separate back support. In exemplary embodiments of the invention, altering the chair position allows for the exercise of different components of the patient without having to fundamentally change the configuration of the apparatus. As mentioned previously, the chair 702 may optionally also tip forward, assisting a patient into and out of an exercise position. Optionally, the chair allows free leg movement.

FIGS. 8A-8C depict a support chair 702 in further additional embodiments of the invention. FIG. 8A shows a chair which can be lowered by a piston 800. Lowering of the chair can assist the patient into a rehabilitation apparatus or can be incorporated into a particular exercise for rehabilitating gait. FIG. 8B shows the chair 702 in a higher position than in FIG. 8A. In exemplary embodiments of the invention, the chair 702 moves up and down depending on the individual needs of the patient. It can also be seen that a torso support 802 can be optionally included with the support chair 702. In an exemplary embodiment of the invention, the torso supports open to allow the entry of a patient into the chair. FIG. 8C depicts the support chair 702 in a fully "tipped" condition whereby in some exemplary embodiments of the invention a patient is assisted

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into exercise (standing) position by a tipping support chair. In an exemplary embodiment of the invention, the chair 702, and optionally other rehabilitation apparatuses, is used to evaluate and teach a patient how to rise from a sitting position to a standing position. During this exercise the patient is optionally supported, partially supported or not supported depending on the needs of the patient. Optionally, the chair 702 is used by the patient to rest before, during or after exercise.

As described above, various sensors can be affixed to the patient and/or the various rehabilitation apparatus components in order to accurately gauge the progress of the patient's rehabilitation in exemplary embodiments of the invention. A wide variety of sensors can be used either alone, or in combination, for this purpose. The sensors can be loosely divided into two types: the first are sensors pertaining to the patient (e.g. body part location, physiological responses), while other sensors are used to gauge the disposition of the chair (e.g. position/orientation of chair components).

In order to gather information on the patient during rehabilitation, sensors are optionally attached to the patient's body. For example, positional sensors are optionally attached to body parts such as the arms, chest, head, feet, hands, and/or legs. These positional sensors are used to determine the location of the various body parts while exercising. Analysis of these location measurements assists with recognizing overall patient movement, including overcompensation for weak body parts by stronger body parts and the like.

Another type of sensor that is optionally used during a patient's rehabilitation is a pressure sensitive sensor. Through the measurement of a patient's exerted pressure in a particular location (e.g. foot pedal 306), it can be determined how dependent the patient is on that body part for stability and/or body control. Pressure sensors are optionally used with the hands, legs, feet, arms, rear end, head, and torso. In an exemplary embodiment of the invention, analysis of the collected pressure data illustrates if the patient's gait is balanced, and if not, where the deficiencies in the gait are situated. An inordinate amount of pressure on one leg for example would tend to indicate that the patient can't adequately use the other leg. The patient's rehabilitation program could then be tailored to work on balance the use of both legs to overcome the deficiency. Force can optionally be measured using pressure sensors. A patient who extends towards a target can activate a pressure sensor which detects how much pressure (i.e. force) the patient could exert on the target. In an exemplary embodiment

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of the invention, pressure sensors are used for measuring both strength and balance in combination.

In an exemplary embodiment of the invention, other sensors, such as muscle tension and electromyography ("EMG") sensors are used to monitor a patient's physiological responses to rehabilitation. Analysis of measurements taken from these sensors help identify which parts of the patient require further rehabilitation and allow planning of future rehabilitation strategy. Optionally, pulse measurement or breathing rate sensors are used.

In addition to or alternatively to sensors for monitoring the patient, sensors are optionally provided for monitoring the operation of a rehabilitation apparatus in an exemplary embodiment of the invention. Sensors are optionally affixed to any component of the rehabilitation apparatus for tracking the position of those components. One type of sensor of this purpose is a magnetic-based position tracking sensor. Ultrasonic and optical positions sensors are known as well. Of particular use is comparing sensor readings from the apparatus with sensor readings from the patient. Comparative analysis of this data indicates patient response to specific movements from the apparatus. Deficiencies in the patient in response to these apparatus movements point to areas needing further rehabilitation.

Optionally, all of the methods and apparatuses described herein can be used with children, teenagers, adults, young and old alike. Optionally, all of the methods and apparatuses described herein are altered depending on the patient's physiological profile, including factoring in amputations, if any. Optionally, all of the methods and apparatuses described herein are adapted for use by patients who require electrical control of at least one body part (e.g. patients with spinal column blocks).

Training of gait is not limited by the particular examples shown above. In particular, gait rehabilitation can be used, for example for supplementing the fine motor control rehabilitation methods described in U.S. provisional application 60/566,079, the disclosure of which is incorporated herein by reference. For fine motor control, a particular gait should be maintained by the patient while applying fine motor control. Fine motor control tasks can be carried out while sitting down.

Gait rehabilitation can also be combined with neural rehabilitation. For example, U.S. provisional application 60/604,615, the disclosure of which is incorporated herein by reference uses neuronal sensing to determine when an action should be triggered. EEG signals can be used as feedback for gait-related activities.

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Gait training can be used with EMG. For example, US provisional application 60/566,078, the disclosure of which is incorporated herein by reference, gait sensing can be used in addition to EMG or to determine when EMG should be delivered.

5 Gait training can be used with balance training, for example such as described in attorney docket number [414/04212], filed on even date with the instant application in the USPTO and with at least one common inventor, the disclosure of which is incorporated herein by reference. In one example, sitting balance training is used prior to or as an adjunct to gait training.

10 Music can be used for gait training, for example such as described in attorney docket number [414/04172], filed on even date with the instant application in the USPTO and with at least one common inventor, the disclosure of which is incorporated herein by reference. In one example, music is used to indicate timely stepping and gait stride by the patient. A channel which is too loud may be used to indicate a body portion applying too much force. Silence may be used to indicate proper gait, while an anomalous gait will generate a cyclical tube and as proper gait is lost and alarm may increase in amplitude.

15 The present invention has been described using detailed descriptions of embodiments thereof that are provided by way of example and are not intended to limit the scope of the invention. The described embodiments comprise different features, not all of which are required in all embodiments of the invention. Some embodiments of the present invention utilize only some of the features or possible combinations of the features. Variations of embodiments of the present invention that are described and embodiments of the present invention comprising different combinations of features noted in the described embodiments will occur to persons of the art. When used in the following claims, the terms "comprises", "includes", "have" and their conjugates mean 20 "including but not limited to". It should also be noted that the device is suitable for both males and female, with male pronouns being used for convenience. The scope of the invention is limited only by the following claims.

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CLAIMS

1. A method for gait rehabilitation, comprising:
 - 5 identifying deficient gait elements;
exercising said deficient gait elements individually using a rehabilitation apparatus; and
exercising said deficient gait elements in concert using said rehabilitation apparatus.
- 10 2. A method of Claim 1 further comprising exercising a complex gait element.
3. A method of Claim 2 wherein a complex gait element is chosen from the group consisting of balance, overcoming obstacles, climbing steps, movement up slopes and
15 varying speed.

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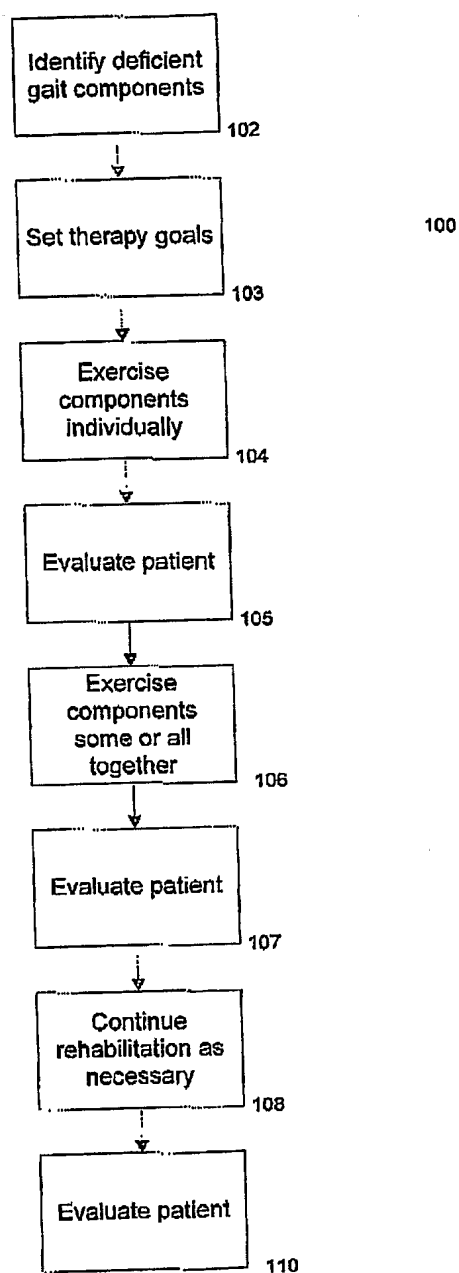


FIG. 1

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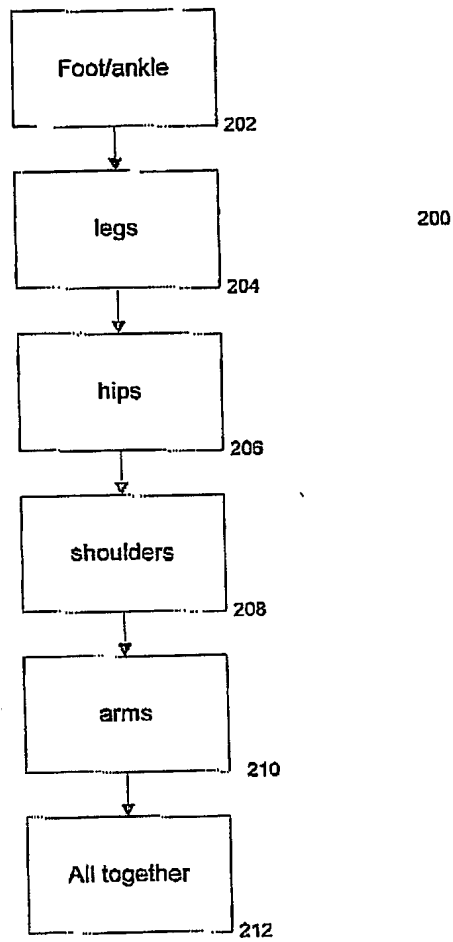


FIG. 2

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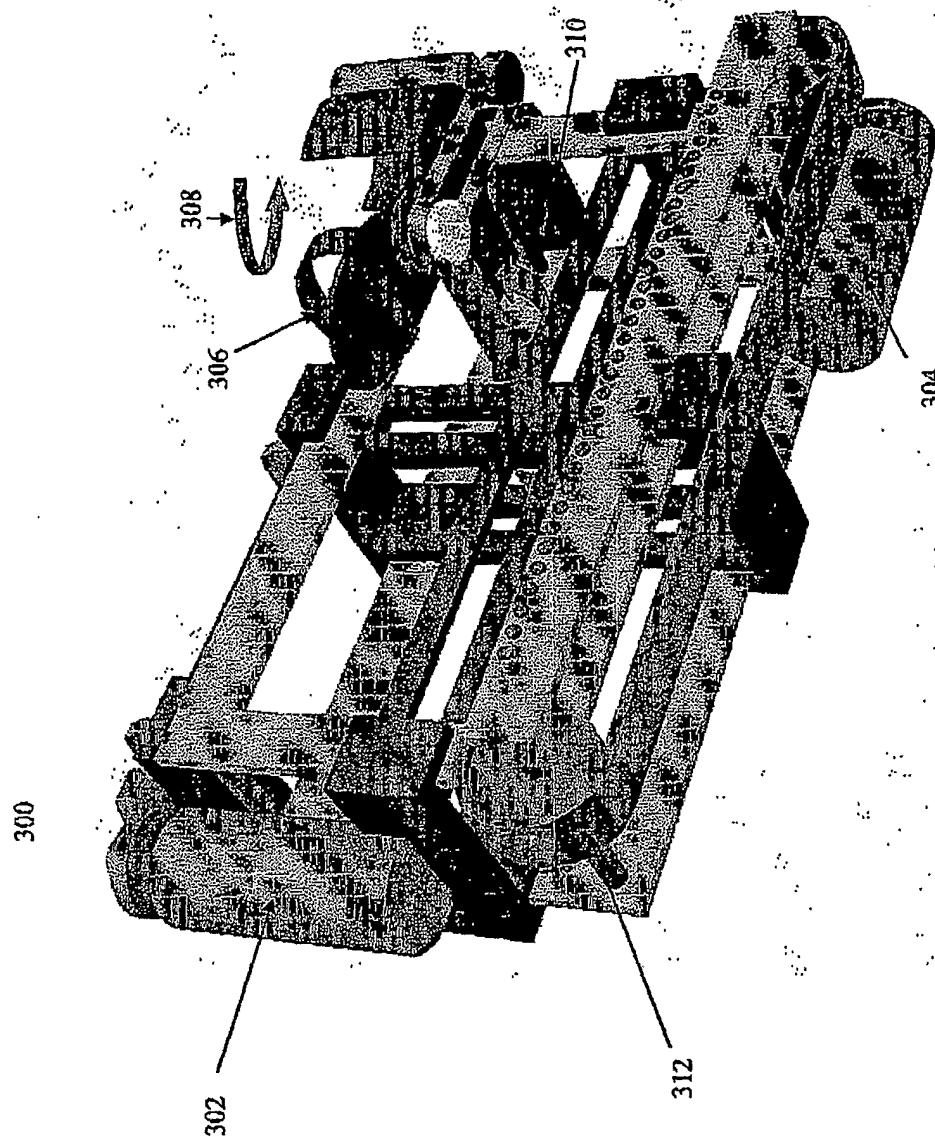
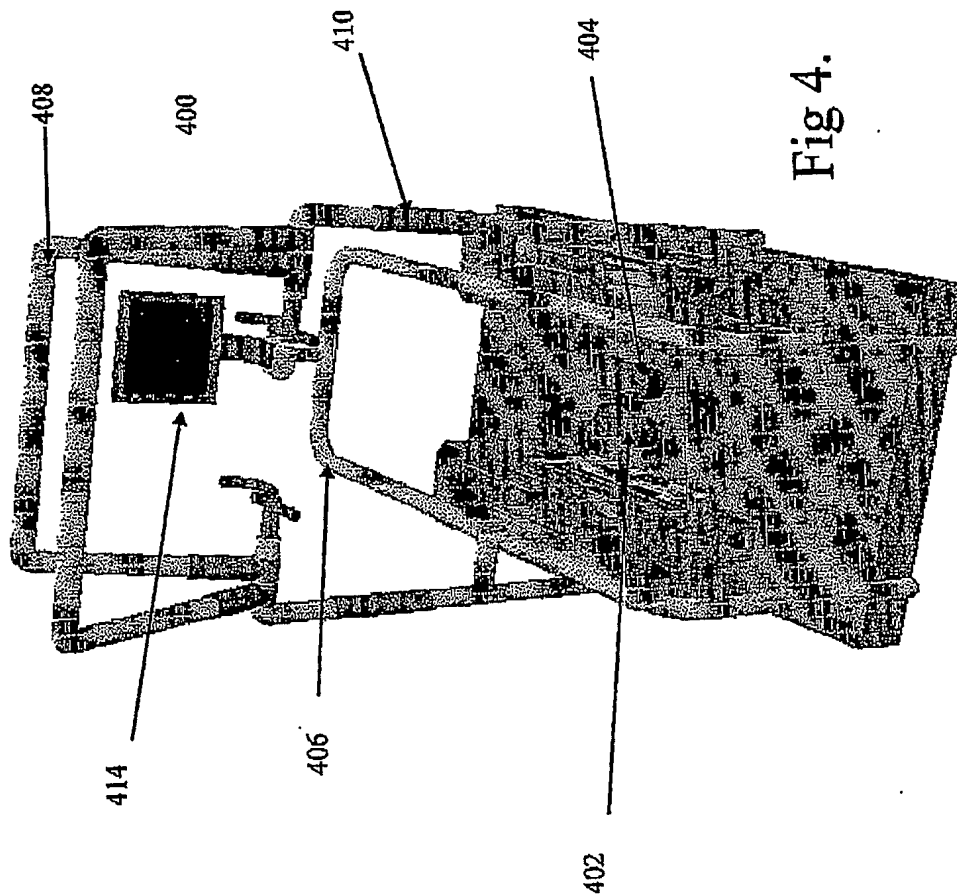
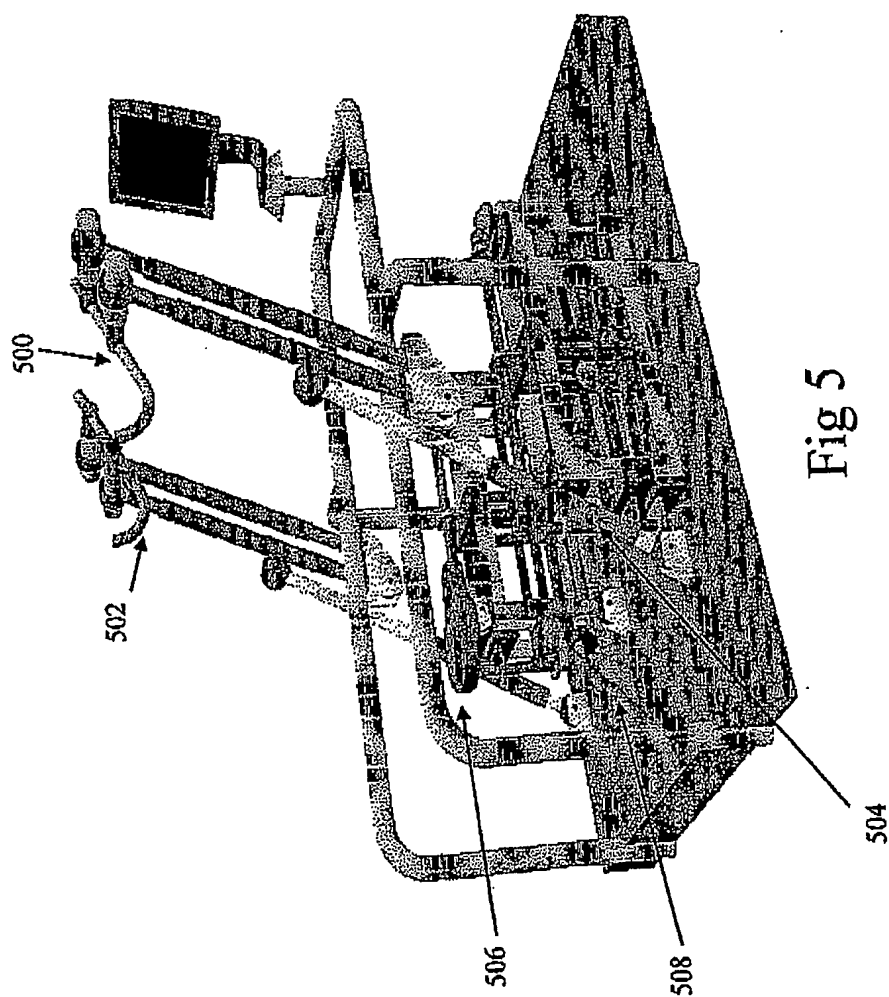


Fig 3.

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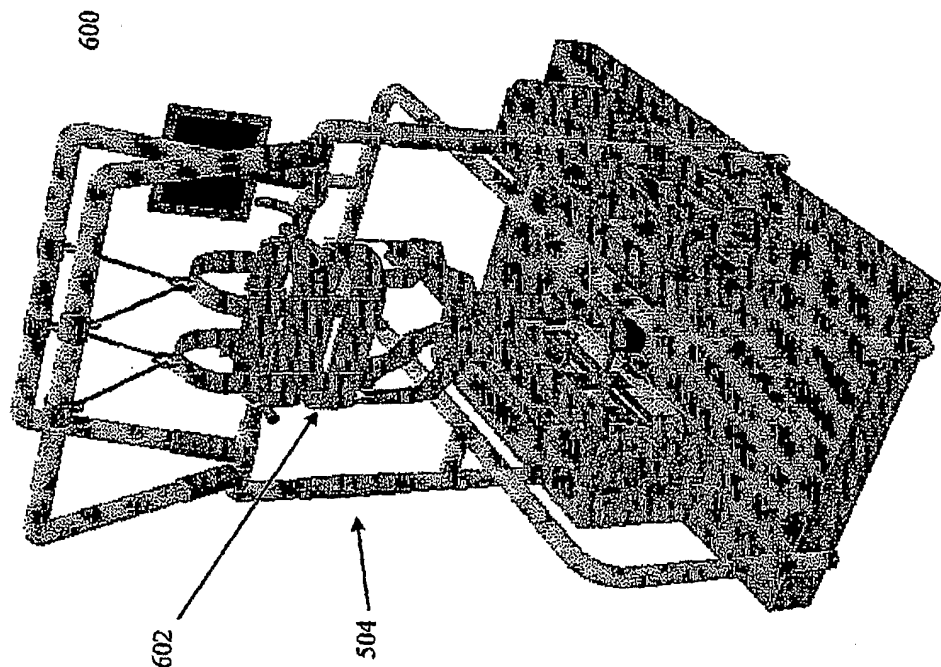


Fig 6

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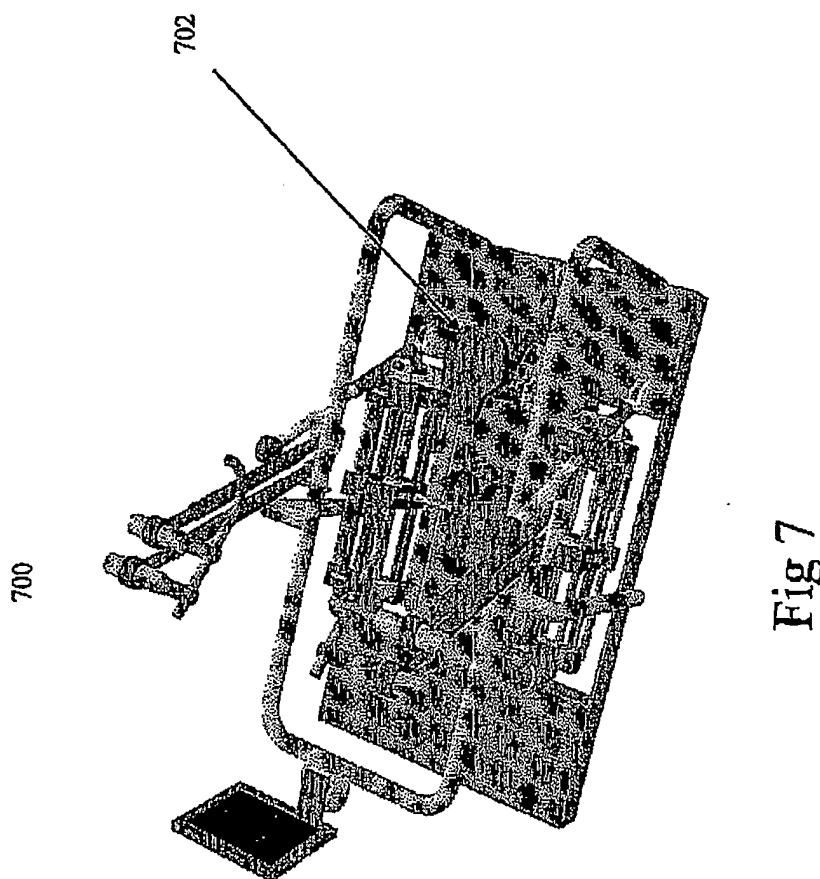


Fig 7

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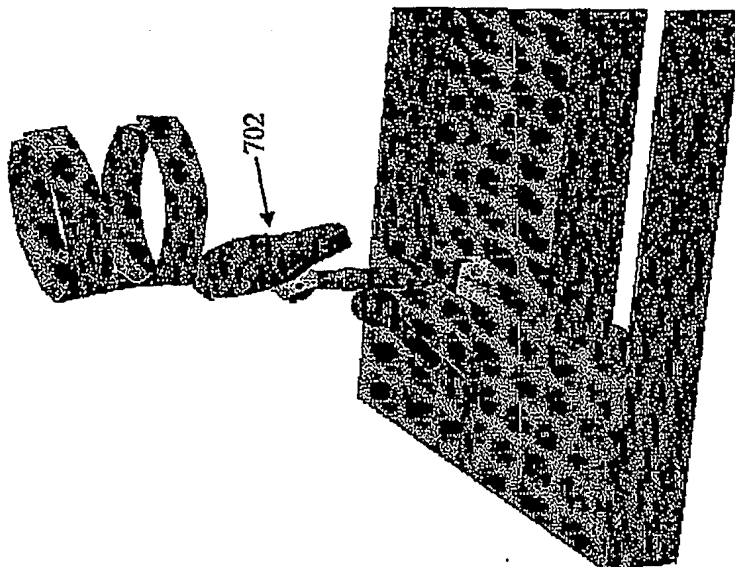


FIG. 8c

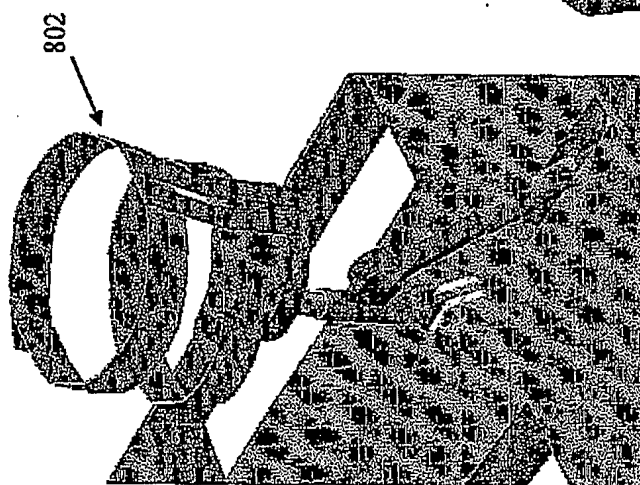


FIG. 8b

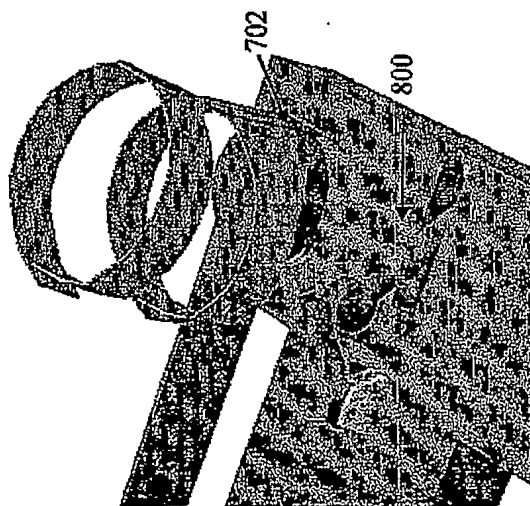


FIG. 8a

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